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THESIS

CONTAINER OPERATIONS AT ARMY MUNITIONS DEPOTS

by

Carolyn M. Kresek

March 1995

Thesis Advisor: Michael Bailey

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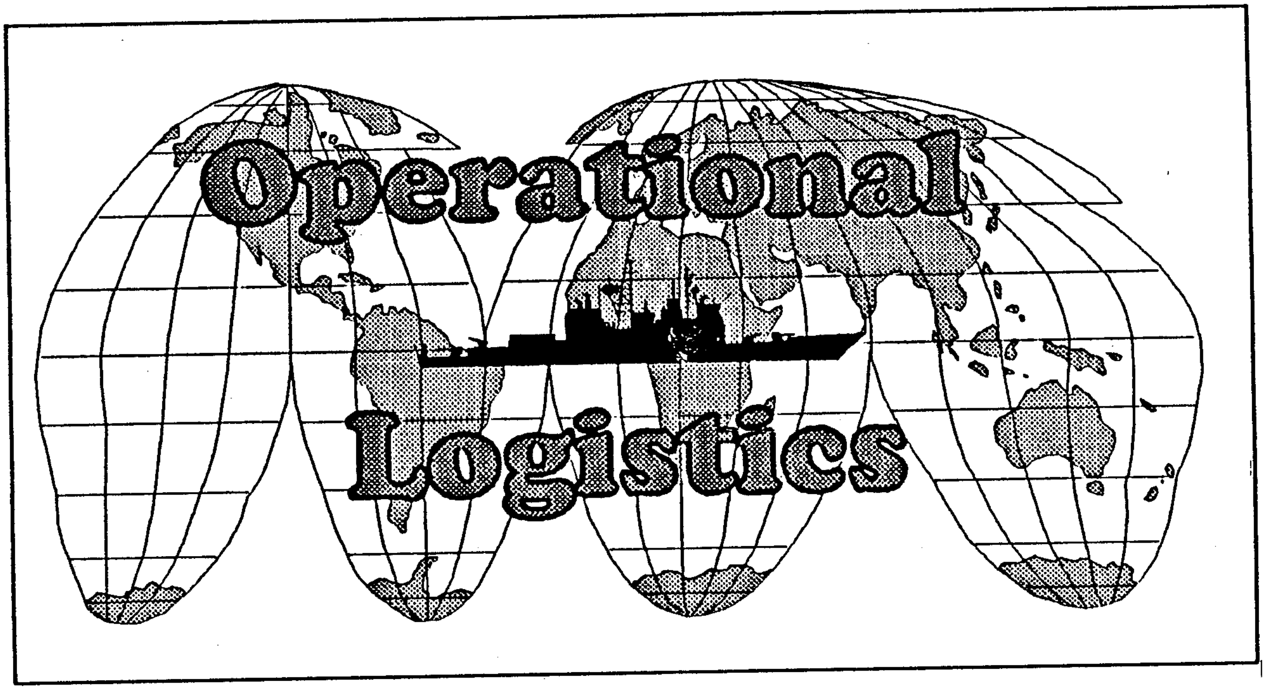
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CONTAINER OPERATIONS AT ARMY MUNITIONS DEPOTS

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ABSTRACT

This thesis examines the use of a simulation model as a method Industrial Operations Command, U.S. Army, can use to assess container operations at its eleven munitions depots. The model, called **AmmoBox**, is tailored to depot container procedures and equipment resource constraints. It provides data on daily container output, and container processing time. Hawthorne Army Depot is used to illustrate the process. The model approximates the depot's container capability, and the simulation results assist to determine the equipment augmentation needed to meet depot mobilization goals. Container enhancement projects are also evaluated with **AmmoBox.** The model-generated data reflect the impact of changes to depot procedures and infrastructure. These data on daily container output and container processing time are recommended for use in a more detailed decision support system for funding and prioritization of depot projects.

THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application these programs without additional verification is at the risk of the user.

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The author would like to acknowledge the technical support provided by Mr. Roger Straight of Military Traffic Management Command-Transportation Engineering Activity. His timely feedback, and his patience in explaining munitions operations was much appreciated. The greatest appreciation is also extended to the people of Hawthorne Army Depot. Their support was instrumental to this thesis effort.

EXECUTIVE SUMMARY

Through the Army Strategic Mobility Program (ASMP), efforts are underway within the munitions logistics system to more fully utilize container operations. Capability studies have identified infrastructure shortfalls and have forwarded corrective recommendations. This thesis focuses on one specific area within the ASMP, the Army ammunition depots and activities which originate munitions shipments.

Industrial Operations Command (IOC), U.S. Army, oversees eleven munitions sites in the United States. Each year, IOC identifies projects and equipment requirements needed to enhance munitions shipments at its depots. Projects are prioritized within each budget year, and budget account (e.g., Operations and Maintenance, or Military Construction). IOC desires a means to reduce subjectivity from this annual review process, and establish a ASMP project ranking and evaluation using objective criteria. Some of the methods used to develop these criteria can also be employed to assess depot container capability, and to identify depot resource shortfalls.

A simulation model was developed to emulate the process of preparing, stowing, and shipping containers of munitions at an Army ammunition depot. While each depot's operations are unique, generic processes were modeled. These included arrival of the containers at the depot; inspection and repair of the container; movement of the containers to a stuffing location; stuffing the container with the munitions; and loading of the container onto a truck or train for transport off-site. The model, **AmmoBox**, provided measures of daily container output, and container processing time.

To illustrate the use of this simulation model, **AmmoBox** was tailored to operations at Hawthorne Army Depot (HWAD). First, it was used to assess the depot's capability to meet its mobilization goal of 188 containers per day. Given current depot equipment resources, the simulation showed a daily output of only 119 containers. The model indicated extensive delays in operations due to a shortage of Container Handling Equipment (CHE) and transfer tractors. Additionally, the number of container inspection sites appeared to contribute to container output capability. These three factors were examined in greater detail. Shortfalls in equipment resources were identified and a recommendation made on the equipment augmentation needed to meet mobilization requirements.

Second, two hypothetical ASMP projects were reviewed using **AmmoBox**. Data was generated on the projects' effects on container output and processing time. One project changed container production procedures; the other infrastructure. Two performance measures, daily container production, and improvement in container processing time were then used as the inputs to a proposed decision support system. Intriguingly, cases were found where container output would improve simultaneously with a decrease in efficiency (i.e., time to process the container would increase). Historically, depot performance has been measured solely based upon daily container production. The author recommends an alternative measurement geared towards container processing efficiency be used, as well, in evaluating and prioritizing ASMP projects. Container output would continue as an important criteria which must be met by the proposed

enhancement project, but it would not drive the funding decision. Instead, IOC could adopt a minimum output requirement for each depot. This would bound the choices of projects to be funded, and serve as a constraint within the decision support model. The enhancement projects could then be prioritized based upon their contribution to depot efficiency.

I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to develop methods the U.S. Army Industrial Operations Command can employ to evaluate and prioritize projects at its eleven munitions sites. The end result of each improvement project is to enhance container shipping operations at munitions depots located in the United States. A simulation model will be used to examine container procedures at Hawthorne Army Depot. The simulations will provide some insight into current practices, and develop measures of effectiveness for grading enhancement projects.

B. BACKGROUND

Weapon systems have evolved dramatically from those employed during World War II, yet the logistics system used to supply the field with the bullets and bombs for these systems has changed little. Originating at Army ammunition depots in the United States, munitions are sent to the field using essentially the same delivery system employed during World War II. Palletized munitions are loaded from the depots onto trucks and trains, transported to loading ports, and stowed in holds of breakbulk cargo ships for their sea transit. This reliance on breakbulk operations is considered antiquated, and has been

largely replaced in the commercial transportation system through the use of containers and the emergence of intermodal networks (De La Pedraja, 1992).

Policy makers acknowledge the efficiency and effectiveness of containers, and the Department of Defense (DoD) has extensively studied the use of containers for its logistics system. These efforts focus on the shipment of resupply and munitions. In 1970, the Army used containers for the first time to ship munitions to Vietnam. This early experiment proved successful, and led to the Army's procurement of containers called MILVANs specifically designed for munitions (Transportation Systems Center (TSC), 1988, pp. 46-49). Containers are used by the Marine Corps for storage of munitions on Maritime Prepositioned Ships, and by the U.S. Army for munitions shipments from the United States and to installations in Germany. Most recently, TURBO CADS 94 tested the use of commercial containers to move munitions to and from the West Coast. Despite success using containers, Operation Desert Storm units received 95 percent of their munitions via breakbulk shipments (Corsano, 1993, pp. 21). With 25 years of study, research, and planning, the infrastructure necessary to exploit the efficiencies of container movement has not fully been implemented within the DoD logistic network.

Through the Army Strategic Mobility Program (ASMP), efforts are underway within the munitions logistics system to more fully utilize container operations. Capability studies have identified infrastructure shortfalls and have forwarded corrective recommendations. This thesis focuses on one specific area within the ASMP, the Army ammunition depots and activities which originate munitions shipments. The thesis will

provide methods to measure the effectiveness of proposed infrastructure projects, and identify issues which need to be addressed for the efficient movement of munitions using containers.

C. THE USERS

There are two primary users for data and procedures developed herein. They are the Industrial Operations Command (IOC) and the Military Traffic Management Command, Transportation Engineering Activity (MTMC-TEA). Both are Army commands.

Each of the Service components assumed responsibility for their unique munitions supply system until the end of the Vietnam War. In 1975, these activities were consolidated by assigning the Army as the single manager for conventional ammunition (TSC, 1988, pp. 46). The Army Armament-Material Readiness Command became the Army's agent for overall responsibility for Continental United States (CONUS) munitions plants, depots and activities. The Army received additional tasking to formulate and implement a centralized Containerized Ammunition Distribution System (CADS). The acronym CADS is still used today. The Armament Material-Readiness Command, however, has undergone several name changes and is now known as the Industrial Operations Command (IOC).

IOC oversees eleven munitions sites in the United States. For purpose of this thesis, all munitions sites will be referred to as depots. The depots' missions are varied

including production and renovation, storage and shipment, and demilitarization and disposal of conventional ammunition. IOC categorizes its depots using a three-tier system. Tier One depots are deemed most critical and form the active core of IOC assets. Tier One depots are fully manned. Tier Two depots are important to DoD war fighting capability but are only partially manned during peacetime. Lastly, Tier Three depots serve predominately as the long-term storage sites for obsolete munitions (Welker, 1994, pp. 22).

Military Traffic Management Command - Transportation Engineering Activity (MTMC-TEA) is a secondary user for material within this thesis. MTMC-TEA conducts surveys and assessments on ports and depots to determine their capabilities to meet mobilization requirements. Engineering studies evaluate depot equipment assets, internal transportation structure (rail and road), and site procedures. From this data MTMC-TEA reviews depot shipment potential for both breakbulk and container operations. If shortfalls exist between the Army Strategic Mobility Program (ASMP) requirements and depot capability, MTMC-TEA provides recommendations for bridging the requirement - capability gap. MTMC-TEA reports address additional needs for upgrade and repair of existing depot infrastructure, such as road and rail. MTMC-TEA's recent efforts in this area have included the use of simulation to assess throughput capabilities.

Recommendations from the engineering reports form the basis for IOC sponsored projects at each depot. Funding for the projects is sought annually by IOC through the

Program Operation Memorandum (POM) process and each proposed POM project is aimed at improving or maintaining depot capability for container munitions shipments.

D. THE RESEARCH QUESTION

Funding is not available for all IOC sponsored projects. During each budget cycle, decision makers consolidate all projects into a single request. The request covers the current fiscal year, one budget and four out-years. Projects are ranked with others for that year in either the Military Construction, or the Operations and Maintenance budget line (AMCCOM, 1994). IOC desires a means to remove subjectivity from the process and establish project ranking through evaluation of objective criteria. This thesis explores several methods and measures of effectiveness which could be used in this process. Secondly, some of the methods can be utilized to provide IOC with data on current container capability at its depots including their ability to meet ASMP requirements.

E. SCOPE AND LIMITATIONS

Each of the eleven depots are uniquely configured. A simulation designed to capture the spirit of operations at Hawthorne Army Depot can not be used for Blue Grass Army Depot. Modeling each of the eleven depots exceeded the time available. As a result, a simulation program for only Hawthorne was designed. The model development for this site can be used to tailor similar simulations to the other remaining depots. The simulation program developed does not pretend to capture the intricacies of all operations

at the site. Only aggregate container shipment procedures were modeled. The method of analysis and measures of effectiveness developed are applicable to all depots.

F. THESIS ORGANIZATION

This thesis is presented in six chapters. Chapter I serves as an introduction to the research issues. Chapter II gives the reader background on the different modes of shipment, specifically the differences between breakbulk and container operations. Chapter III discusses the processes simulated in the model **AmmoBox**. This model is used in Chapter IV to assess container operations at Hawthorne Army Depot. Chapter V briefly describes the use of simulation-derived data in a decision support system. Chapter VI summarizes thesis research findings and their applicability to IOC and MTMC-TEA.

II. CONTAINER OPERATIONS

World War II provided the impetus and inspiration for the use of containers to ship cargo (De La Pedraja, 1992, pp. 200).

> Under the wartime emergency, major savings in speed, efficiency, and cost had been made by sending mixed cargo inside palletized boxes (boxes stacked on top of flat trays). So impressed was the War Shipping Administration with the savings in time and labor that it conducted special trial runs using containers instead of palletized boxes and achieved phenomenal results.

In the early 1960's, this method for transporting cargo was introduced into the commercial industry. Two shipping companies, Sea-Land and Matson, began using containers for ocean transport of cargo (Corsano, 1993, pp. 7). Previously, cargo transported by sea was loaded on pallets in the holds of breakbulk ships. Intermodal networks now exist to move cargo in containers from its origin to its destination using truck, rail, and ship. Containerization has succeeded because it saves the shipper and the consignee money. There are many advantages to containerized cargo.

- Labor costs for moving cargo from one transportation mode to the next are reduced. It takes less time to move a container from a rail car to a container ship than it does to move the equivalent dozen pallets from a boxcar to a breakbulk ship.

- Administrative savings are realized due to fewer in-transit inventories.

- The primary savings to the customer is through reduction in transit time for moving their goods to destination.

The cost savings are immense, but so too is the capital investment to implement a containerized intermodal system. The intermodal container-support infrastructure

investment is the principle disadvantage to container operations (Johnson and Garnett, 1971, pp. 50 - 51). DoD has extensively studied the use of containers for the shipment of war materials. The U.S. flagged commercial fleet can not support the mobilization sealift requirements of the military without the extensive use of container ships, there are simply too few breakbulk ships remaining in service. In addition, the commercial sector has in place an entire intermodal network of rail and truck to expedite shipments made using containers. In general, unit equipment (e.g., tanks, construction equipment, tank trucks, etc.) are not conducive to containerization. However munitions and resupply materials can successfully exploit the advantages of containers and the speed of container shipment.

A. BREAKBULK AMMUNITION SHIPMENTS

Breakbulk operations are labor, time, and material intensive. Breakbulk ammunition shipments are packaged on pallets. At the depot, the pallets are carefully loaded into truck beds and boxcars. Each pallet must be stowed in a manner which prevents shifting or jostling in transit. To effect safe transport, a procedure called blocking and bracing is performed for each load. Lumber (called dunnage) and cloth straps are used to secure the pallets in place. The blocking and bracing procedure is the most time-intensive phase of the loading operation.

When the munitions arrive at the seaport, the pallets are discharged from their land transport and prepared for loading in the ship. Each pallet must be loaded individually. The ship itself is prepared to receive the explosive cargo. The cargo holds are lined

(sheathed) with wood to prevent inadvertent contact with the ship's metal structure. This is necessary to limit the possibility of a metal-to-metal spark between the ship's structure and the palletized munitions. It takes an additional one to two days to sheath a ship (Yocum, 1995). Lumber became a scarce resource, especially at island ports such as Guam, and Hawaii. So scarce was sheathing material that a load of mahogany from the Philippines was used to sheath one ship. Once pallets are loaded into the ship's holds, they must be blocked and braced with additional dunnage to prevent shifting during the voyage. The process is repeated still again when the munitions are discharged from the ship and moved by land conveyance to the user command.

B. CONTAINERIZED AMMUNITION SHIPMENTS

Rather than moving pallets, munitions can be loaded into containers for its journey from the depot to the area of operations. Containers are large metal boxes which come in a variety of sizes and types. The box of choice for munitions is a MILVAN. This type of container is a 8-feet wide, 8-feet high and 20-feet long rectangular box. The box has an internal constraint system with built in rails and adjustable crossbars to assist in the secure stowage of explosives (Corsano, 1993, pp. 39). Commercial twenty foot containers can also be employed, as well as 8-feet wide, 4.25-feet high and 20-feet long containers known as half-highs. The half-highs have no metal top, but instead are covered with a tarpaulin. These unique containers are used for transport of very heavy munitions whose density-to-volume ratio makes the use of the MILVAN impractical (Corsano, 1993, pp. 41). The

weight of normal munitions prevents them from being moved in the commercially more common 40 foot containers.

Munitions on pallets are loaded directly into the containers. Blocking and bracing occurs inside the container. The containers are then loaded on truck chassis and rail cars for transit to the seaport. At the port the container, not the individual pallets of munitions, are discharged from their land conveyance and loaded onto container ships. The Joint Chiefs of Staff (JCS) planning calls for the sea transport of the munitions using U.S. flagged commercial container ships. No special preparation of the ships is required. The commercial vessels are designed to accommodate both 20 and 40 foot boxes. The container ships need not be sheathed, as the munitions are stowed securely in their containers. No additional blocking or bracing of the containers is required. At their destination, the containers can be discharged directly from the ship to truck or rail. Moving munitions by container, eliminates the need to block and brace the munitions at each change of transportation mode.

C. BREAKBULK VERSES CONTAINER AMMUNITION SHIPMENTS

Container shipments thus save costs in terms of labor and material. More importantly to DoD, the time required to move material by containers is reduced. However, there are difficulties associated with container operations. Containers of munitions weigh, on average, 14.5 short tons. The forklifts used to move pallets of munitions are not designed to move such heavy loads. Additionally, the size of a container

eliminates its handling by a conventional forklift. Consequently, at the depot, seaport and intermediate transportation junctions, container-capable forklifts and other container handling equipment is required. The cost and availability of this container handling equipment is not a difficult problem for shipments within the U.S. It could be an insurmountable problem to solve in some theaters of operation where container handling equipment would need to be positioned prior to the arrival of the munitions shipments. This lack of container handling equipment was the primary reason cited by Desert Storm commanders for their reluctance to employ containerized munitions shipments.

Sea ports must also have special equipment for container operations. Breakbulk ships are termed self-sustaining because they are equipped to discharge their own cargo without the assistance of shore-side cranes. Container ships, normally, are non-self sustaining and require special shore cranes to discharge and load the containers. Many third world ports are underdeveloped and incapable of accommodating the modern container ship. Consequently, DoD plans call for the inclusion of both breakbulk and container shipments of ammunition. JCS uses the planning factor of 70 percent container and 30 percent breakbulk. However, as was the case in Operation Desert Storm, the theater commander is the final decision maker on the mix of shipment mode.

D. IMPACT OF SHIPMENT MODE ON MUNITIONS DEPOTS

The depots must be prepared to ship munitions using both breakbulk and container operations. Many depots lack the necessary infrastructure and the equipment for efficient

containerized shipment. This thesis focuses exclusively on depot container operations. Analysis methodology will be established to assess capability. To date, no major mobilization has tested the depots ability for a massive container effort. No data therefore exist to document depot performance under mobilization. A computer simulation is thus used to approximate the depot operations in such an environment.

III. THE MODEL

A. INTRODUCTION

AmmoBox is an object-oriented simulation program which models the process of preparing, stowing, and shipping containers of munitions at an Army ammunition depot. While each depot's operations are unique there are generic steps common in all container operations. **AmmoBox** emulates each of these steps. The basic process includes the arrival of containers at the depot; inspection and repair of the container; movement of the containers to a stuffing location; stuffing the container with munitions; and loading of the container on a truck or train for transport off-site. The simulation can be further refined and tailored to capture the unique methods depot managers have implemented to accomplish their mission.

Equipment availability is a primary constraint to container operations. The number of containers stuffed during a day is dependent upon having sufficient numbers of forklifts to move munitions pallets into containers. Other equipment is necessary to move the containers to and from loading sites. A type of equipment may be needed for many steps within the process. For example, Container Handling Equipment (CHE) is needed to lift the container onto an inspection rack during the inspection phase. It is also required to lift a loaded container onto a rail car. The model examines the impact of resource competition among the container processing steps.

AmmoBox uses two measurements to assess container operations at the depot. The average time required to move an empty container, stuff it, and load it onto a train or truck is the first measure. The daily output of containers from the depot is the second measurement. AmmoBox is predominately a deterministic model with the time to process a container and the depot's container output driven by container operating procedures and the availability of equipment resources.

B. CONTAINER OPERATIONS

1. Container Arrival, Inspection, and Repair

The depot has a small number of containers pre-staged at the facility. To maintain container operations beyond a few days, more containers must be dispatched from Army and commercial sources. It takes seven days for containers to be ordered and shipped to the depots (Shuck, 1994). Once the first order of containers arrives at day seven, the model assumes a continuous daily supply of containers.

On arrival, the container is off-loaded and moved to an inspection site. For efficiency, the off-load and inspection site are normally co-located. This conserves chassis and transfer tractor resources which otherwise would be required to move the box. The inspection phase of operations requires the container to be lifted onto an elevated rack. The box then can be inspected along all sides. Figure 1 diagrams the flow of operations at this stage. In the figure, blocks with bold outlining indicate steps which require more than thirty-minutes.

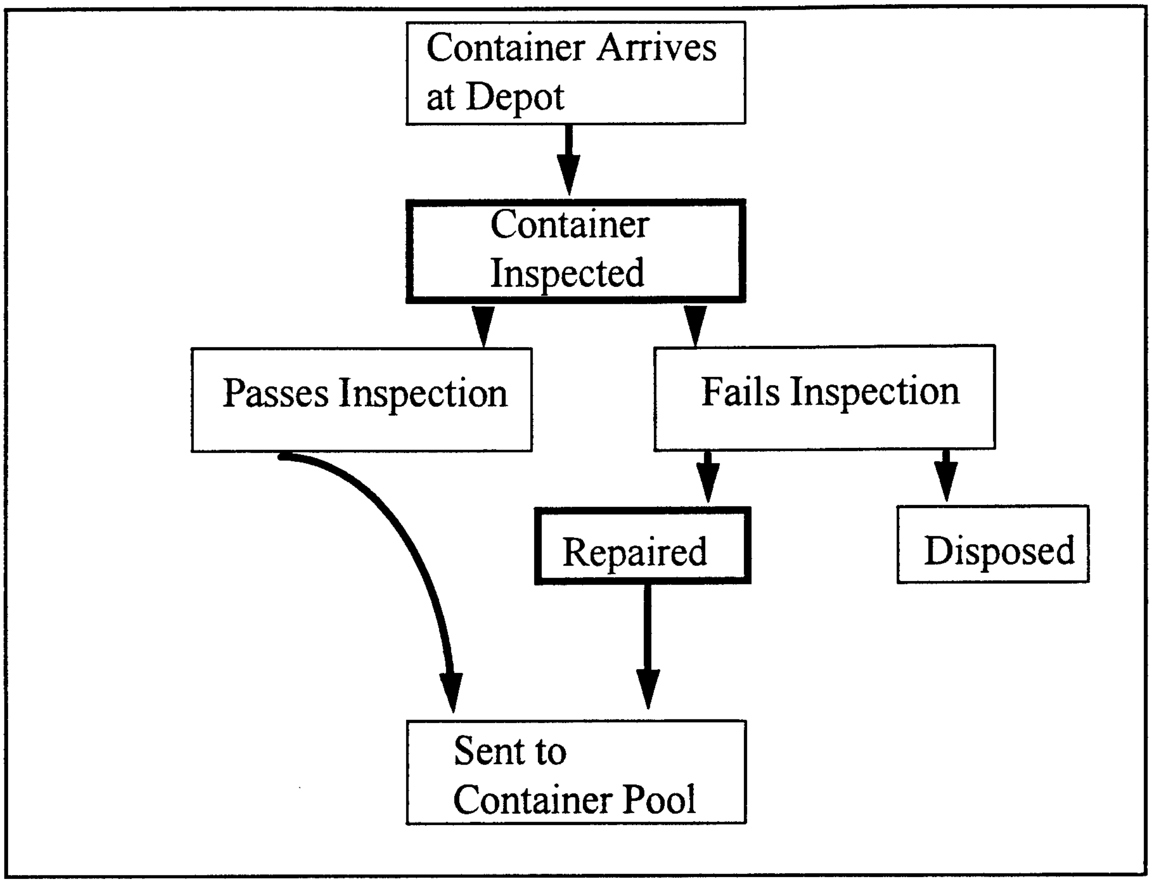

Figure 1. Container Arrival, Inspection and Repair Process Diagram

If the container passes inspection, it is moved to an area allocated to ready-to-use containers. For ease of reference, this area will be referred as the container pool. Containers failing inspection are sent to a repair facility, if available, at the depot. Safety factors require ammunition be transported only in *as new* containers. A box can fail inspection if it has holes, rust, or malfunctioning doors. Containers can also be rejected if previously repaired at key structural joints. Historical rejection rates for containers range from 15 to 30 percent. Damaged containers which can not be repaired by the depots are returned to their source.

2. Container Loading Operations

Inspection and repair of the containers is a necessary preliminary phase. The ultimate goal is to stow the containers with the munitions, and ship them off-site. Figure 2 illustrates this process.

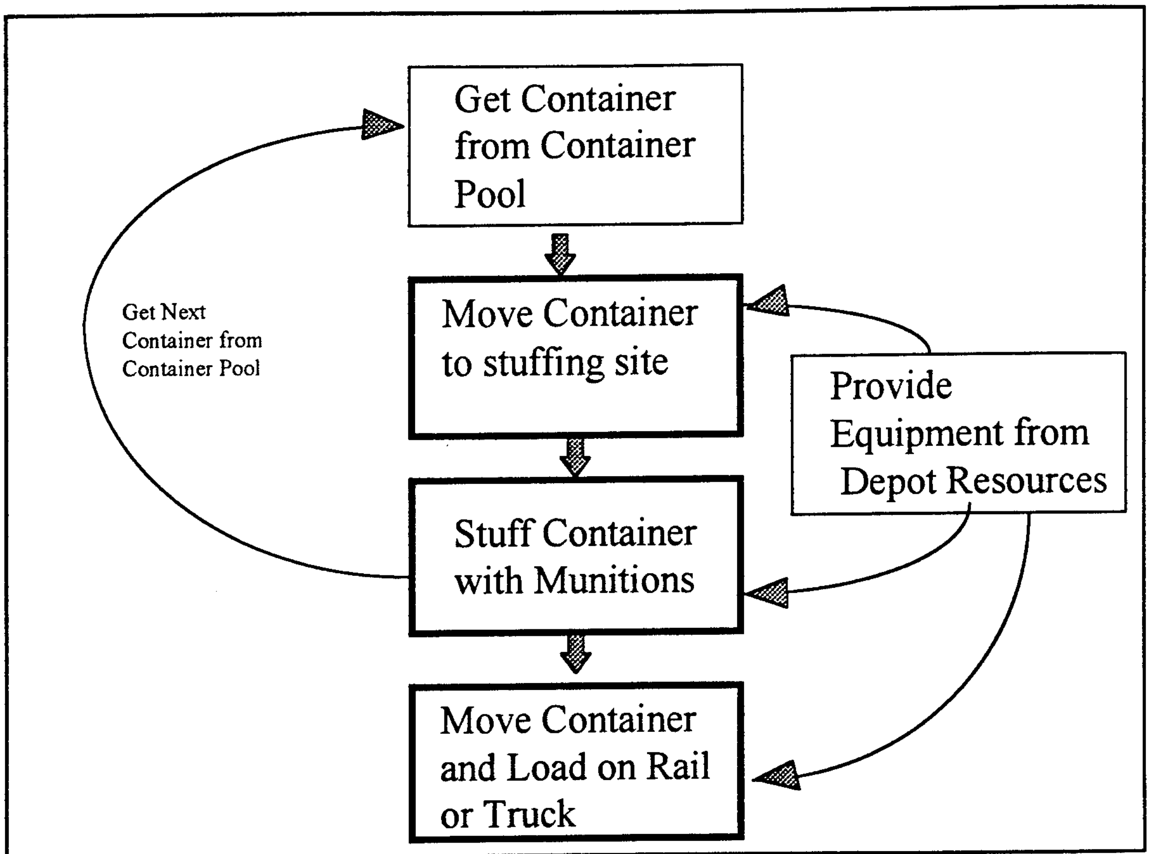

Figure 2. Logic Diagram for Stowing Munitions in Containers

Depot managers tailor each of these events to fit the lay-out and resources at their depots. Some magazines (also called igloos) have rail-capable loading docks; other more isolated magazines are accessible only by roadway. Although the intricacies of all methods were not modeled, two distinct methods of container loading are simulated. The location of container stuffing underscores the differences in the two processes.

In the first method, containers are moved by chassis and transfer tractor from the container pool to the igloo. Munitions from the igloo are loaded directly into the container, blocked, and braced in place. The container is then moved to a truck or rail loading site. Stuffing the containers at the igloos is the preferred mode of operations as it prevents double handling of the munitions. Figure 3 depicts this process for Hawthorne Army Depot (HWAD).

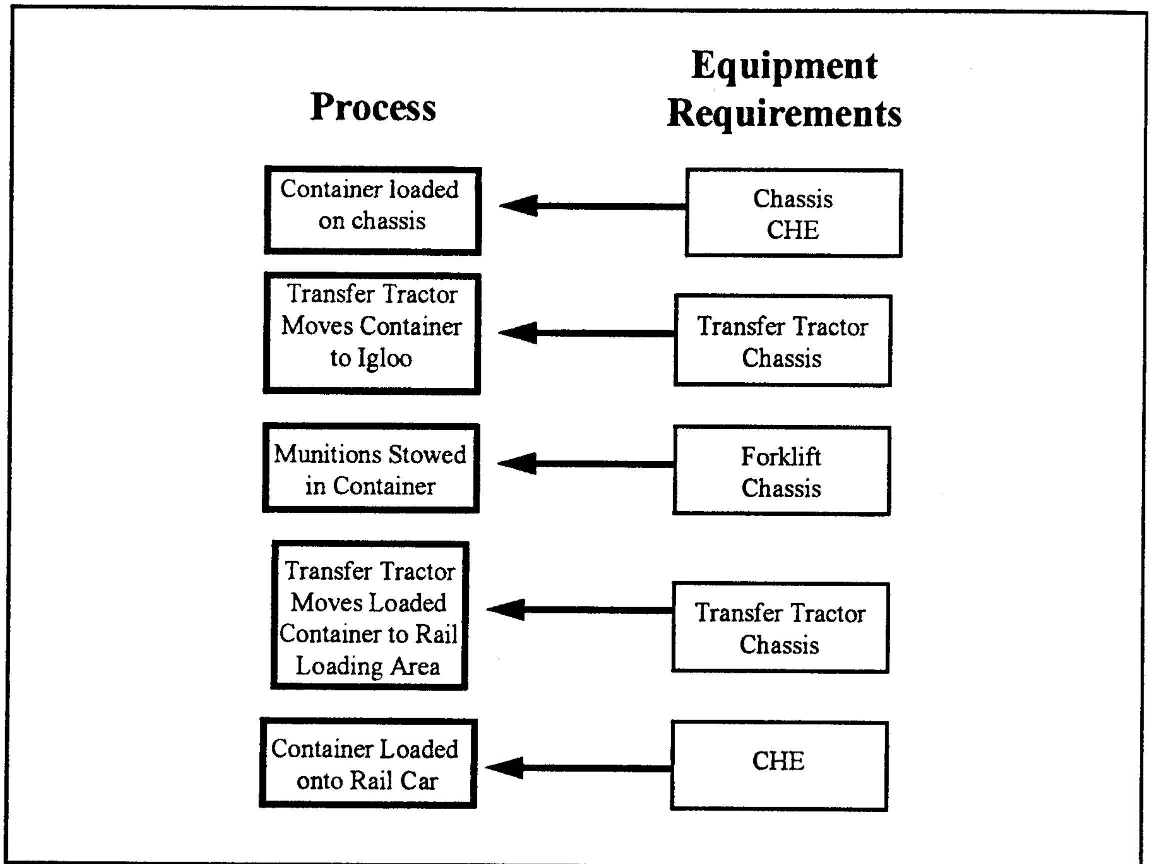

Figure 3. Process of Stuffing Containers at Munitions Magazines

In contrast, containers can also be stuffed at a consolidation location. A semi-trailer is loaded with the munitions from the igloo, and transports the munitions to a

central location for stuffing into the assembled containers. While the munitions need not be blocked and braced within the semi-trailer, the acts of loading and discharging the truck bed adds an otherwise unnecessary time delay to the process (see Figure 4).

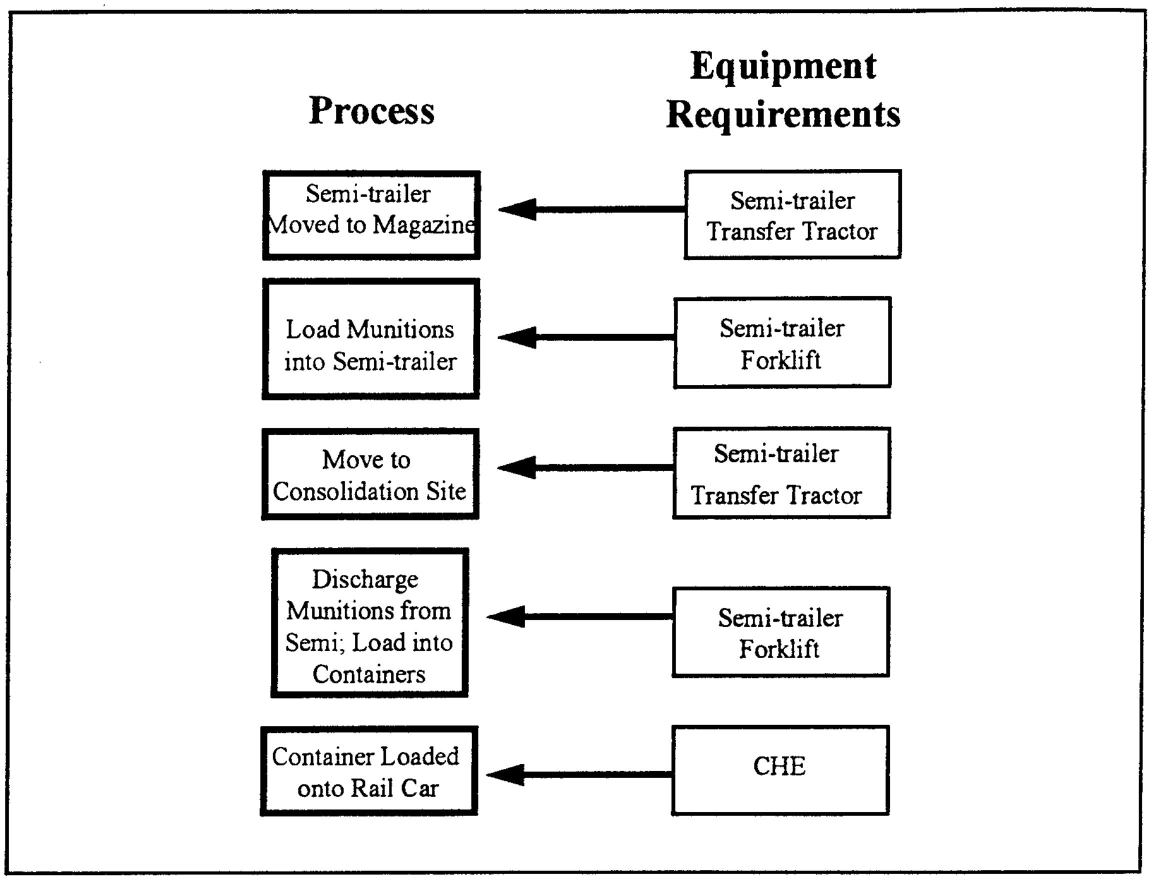

Figure 4. Process of Stuffing Containers at a Consolidation Site

3. Model Implementation

AmmoBox employs three objects to simulate control and movement of the containers through the depot. The first, **DepotObj**, controls the frequency and quantity of containers entering the depot. The second object, **ManageContainerObj** maintains the container pool. Inspected containers are dispatched to work sites upon request. If no

container is available for issue within the pool, the request is held in abeyance until a container becomes available. A Uniform random variable is used to determine if a container will be dispatched for loading at the munitions magazine or a consolidation site. Random variables are also utilized for container inspection results and container repair times. Finally, the **ContainerObj** serves as a notional container which is inspected. repaired, and loaded with munitions.

C. EQUIPMENT USED IN CONTAINER OPERATIONS

Several different types of equipment are needed to load a container with ammunition and prepare it for transport off the activity. For example, the container must be moved from the container pool to the munitions magazine. The container is loaded onto a transport chassis and is then hauled by a transfer tractor to the magazine. At the magazine, forklifts are needed to move the pallets of munitions into the container. *How* each piece of equipment functions is not important; what is critical is its availability. Equipment is therefore modeled as a resource and not by its specific characteristics. Table I lists the types of equipment found at Hawthorne Army Depot and its role in container operations.

Equipment	Use
Forklifts	Loads munitions pallets into containers and semi-trailers
Transfer Tractors	Moves semi-trailers and chassis within the depot
Chassis	Provides the frame and wheel base on which containers are placed.
Semi-trailers	Truck bed to load munitions for transport within the depot
CHE	Used to lift a container. Also used to move containers short distances

Table I. Equipment and Its Use in Container Operations

Three factors are considered when determining the quantity of equipment in the model: depot allowance, equipment availability, and equipment reliability. A munitions depot has an allowance for each type of equipment. From its allocation, a percentage of the equipment may be required for depot functions other than container operations. For example, Hawthorne has a mission to demilitarize and destroy obsolete munitions. Forklifts are needed to carry out this function and a certain number of forklifts must be set aside for this mission. In the model, forklift availability accounts for only the percentage of forklifts dedicated to container operations. Mechanical equipment requires maintenance and repair. Forklift reliability, then, relates to the percentage of available forklifts which are fully operational. To illustrate, 100 forklifts may be at the depot, but only 80 are available for container operations. Of those available, 20 percent may need some sort of maintenance or repair. The end result leaves 64 of the original 100 forklifts ready to be used for container operations. The allowance, availability and reliability are parameters within the model.

ManageEquipmentObj and **EquipmentObj** control and maintain the equipment resources. Requests for resources are issued from the **ContainerObj** as it progresses through the inspection, repair and loading phases. Equipment is issued to the container for the duration of the task, and returned to the **ManageEquipmentObj** upon task completion. If the desired equipment is already in use, the container's process is delayed until the equipment becomes available.

D. THE EXPERIMENTAL PROCESS

The author will focus on three areas in which **AmmoBox** can be used to gain insights into depot operations. A baseline simulation with current depot parameters will be used to determine if the facility can meet demands at the height of mobilization. Second, depot equipment resources will be reviewed to determine if deficiencies in container equipment limit depot production levels. Any equipment shortages will be investigated and a recommended equipment allowance provided. Finally, changes to depot procedures and/or infrastructure will be explored to provide a quantitative measure of a change on depot efficiency. The following chapter will detail the experimental method used and provide analysis on the results obtained.

IV. *AMMOBOX* AND HAWTHORNE ARMY DEPOT

A. BACKGROUND

Hawthorne Army Depot (HWAD) will be used to illustrate **AmmoBox**. The plant is a government-owned, contract-operated depot in Nevada. The largest of the IOC depots, it is a Tier-Two site. HWAD has over 2,600 magazines, and spans a 236 square mile area (MTMC-TEA, 1992, p. 24). Three sources of information were used to tailor **AmmoBox** to procedures and equipment resources at the Nevada depot. A site-visit by the author in August 1994 provided initial information on the environment and procedures used in handling munitions. Second, MTMC-TEA Report SE 92-3a-30, Army Strategic Mobility Plan Outloading Study, was used for initial data parameters and procedures at HWAD. Finally, HWAD personnel reviewed flow diagrams and parameters to ensure accurate depot representation. Outstanding assistance was provided to the author by all members of HWAD, and by Mr. Roger Straight of MTMC-TEA. Model parameters can be found at Appendix A.

B. THE EXPERIMENT

AmmoBox, tailored to operations at HWAD, will be used for two experiments. Annually, depots complete a Department of Defense Form 1726, OutLoad and Receiving Capabilities Report, in which managers estimate their facility's production of containers

during peacetime and mobilization. The first experiment compares the container output achieved using **AmmoBox** with that reported by HWAD on DD Form 1726. If differences in output figures exist, depot resources will be manipulated within the model to determine the resource mix required to meet HWAD's mobilization goals.

The second experiment will use **AmmoBox** to model changes to HWAD container operations, and infrastructure. This experiment will illustrate the use of simulation to quantify the impact of IOC projects on depot container capability.

C. MEASURES OF EFFECTIVENESS

The goal of **AmmoBox** is to provide decision makers with the ability to determine current depot capability and assess the impact of proposed changes to depot resources and operations. Two measures of effectiveness can be helpful in this assessment. The first measure calculates the time required to process a container for loading operations. The processing time begins with the dispatch of the container from the container pool to the time it is ready for loading on a truck or train. The inspection and repair time is not figured into this calculation because an inspected containers could reside within the container pool for a number of days before it was dispatched to a work site. The time to process a container is not intended for use between depots. Rather it is a measure of efficiency to apply between current depot practices and proposed alternatives for that depot.

The second measure of effectiveness is number of containers produced in a day. Container output is the conventional measurement used by IOC and MTMC-TEA. While this is an important figure for assessment of a depot's ability to meet ASMP requirements, it does not provide guidance as to the efficiency of container operations.

While not used as a measure of effectiveness, a third calculation is performed within **AmmoBox**. A simple tally of equipment delays is maintained for delays in excess of fifteen minutes. This calculation can be used by analysts to determine the adequacy of resources at the depot. Additionally, it can identify choke points within the system.

D. BASELINE ASSESSMENT

HWAD loads containers both at munitions magazines and at consolidation sites. The initial simulation assumed a fifty percent split between the two loading strategies. With unlimited resources, the time required to process a container loaded at the magazine is 3.8 hours, and 4.9 hours when loaded at a consolidation site. Appendix A provides a breakdown of time increments for each phase of the process.

Competition for equipment resources can lengthen processing time. A delay occurs if a piece of equipment is unavailable immediately for any phase of the operations. Simulation results show the average time to process a container is 5.1 hours, and the average number of containers processed upon attainment of full mobilization is 119 containers a day. No equipment delays were experienced for forklifts, semi-trailers, or chassis. Numerous delays resulted from waits for transfer tractors and CHEs. In fact, the

number of waits for these pieces of equipment exceeded the total number of containers processed at HWAD. This suggests transfer tractors and CHE resources may be limiting container production at this depot.

AmmoBox assumed five container inspection racks to be available. The time required to inspect the container, as previously mentioned, is not factored into the processing time computation (i.e., containers sent to the container pool would skew processing time results). The model does, however, tally any delays encountered during the inspection process. This number was significant. Of the 150 containers arriving daily to the site, 88 percent waited over 15 minutes in an inspection queue.

E. HWAD MOBILIZATION GOALS

HWAD's most recent OutLoad and Receiving Capabilities Report indicates a capability for processing 188 containers per day at full mobilization (Blackman, 1995). This figure conflicts with the **AmmoBox** baseline assessment of 119 containers per day, given the depots current resources. The author examined several factors to determine what resources significantly impact HWAD's ability to reach its output goal of 188 containers.

The first set of experiments included a 2^4 factorial design experiment. This process examines four parameters, known as factors, each at two levels, or values. Data runs are conducted at all possible combinations of factor-levels to determine the parameters' impacts on container output. In this case, a 2^4 factorial experiment results in 16 simulation

runs (Law and Kelton, 1991, pp. 659-670). Three of the four factors chosen were identified as important in the baseline simulation; namely, the number of transfer tractors, CHEs, and inspection sites. The number of work sites was selected as the fourth factor. While not a factor in the baseline experiment, the number of containers resupplied to the depot on a daily basis was increased from 150 to 200 a day to ensure an output of 188 containers was possible.

A simple regression on the simulation results served to screen factors for the next phase of simulation runs. Only main effects were considered in the screening assessment. Equation (1) provides the linear regression results which yielded an adjusted R-squared value of .72. In the equation, X_1 represents the number of container work sites; X_2, the number of inspection sites; X_3, the number of CHE; and X_4, the number of transfer tractors. The variable Y represents the average daily output of containers. The factor representing the number of work sites at the depot had little impact on container output (t-Test value of .2), and was removed as a factor from subsequent experiments.

$$Y = 67 + .188X_1 + 2.56X_2 + 2.31X_3 + 2.34X_4 \qquad (1)$$

This initial screening was followed by a more detailed, exhaustive experiment. A 3^3 factorial experiment was used to examine the impact of CHE, inspection sites, and transfer tractors on daily container output. Each of these factors were explored at three levels. To further refine results, **AmmoBox** was used for five independent replications (i.e., data runs) for each factor-level combination. This resulted in the collection of 135

data sample points. A complete iteration of combinations and results can be found at Appendix B. Table II shows the factors and levels assessed.

Factor	Baseline Value	Level 1	Level 2	Level 3
Number of Inspection Sites	5	5	6	7
Number of Tractors	26	28	30	32
Number of CHE	7	9	11	13

Table II. Factor and Level Design

Again, a regression model was utilized to analyze the **AmmoBox** generated data. Several regression models were explored with mixed results. A quadratic equation incorporating interactive effects between variables was selected based upon its adjusted r-squared value of .98 and analysis of variance testing. In the equation below, X_1 represents the number of CHEs; X_2, the number of inspection sites; and X_3, the number of transfer tractors. The variable Y represents the average daily output of containers.

$$Y = 435.2 - 56.5X_1 - 65.6X_2 + 12.2X_1X_2 + 1.19(X_1)^2 - .04(X_1X_2)^2 \qquad \textbf{(2)}$$

The regression model is only viable within the experimental range of the factors. Equation (2) does indicate that the relationship between factors is inherently non-linear. Thus, the use of simple analytical models previously used by MTMC-TEA to assess requirements for additional equipment may not adequately address the interactive effects between resources. More helpful, are the results obtained by the simulation runs themselves. To meet the mobilization goal of 188 containers per day, a minimum of 11 CHE, 28 transfer tractors, and six inspection sites are required. There is a strong interaction between the number of inspection sites and the number of CHE.

Approximately the same level of container output (190 containers per day) can be achieved by increasing the number of CHE to 13 and reducing the number of inspection sites to five. The author recommends the former rather than later augmentation of resources, because **AmmoBox** does not account for potential congestion issues from using several CHEs within the same loading areas. The time delays associated with CHE interference could limit actual container output. Table III contains the results of the simulation, and predicted values using the regression model for these factor-level combinations.

Factors-Levels	Simulation Model	Regression Model
11 CHE, 6 Inspection Sites, 28 Transfer Tractors	187	194
13 CHE, 5 Inspection Sites, 28 Transfer Tractors	190	197

Table III. Predicting Daily Container Output

F. *AMMOBOX* AND PROJECT PROPOSAL ASSESSMENT

In addition to analyzing depot capabilities, **AmmoBox** can be used to quantify the impact on infrastructure improvements and production changes to container operations. Four alternatives will be examined. Alternative A requires no change to operations or infrastructure, and is the baseline assessment previously discussed. Alternatives B through D will be compared to this baseline measure. Alternative B changes the location mix for container stuffing. Alternative C attempts to quantify the impact of building container loading pads. Finally, Alternative D combines both Alternative B and C, simulating a change in container stuffing and the addition of container loading pads.

1. The Alternatives

Alternative A and B differ only in the proportion of containers stuffed at the munitions igloo. HWAD loads containers both at the igloo and at consolidation sites. The latter requires additional processing time to load and move the munitions from their storage location. HWAD continues to use consolidation sites, not because the process is more efficient, but because of customer requirements. The Army and Air Force want their units to receive munitions from the same batch-lot packaged together (i.e., in the same container) rather than mixed lot shipments (i.e., different batches in the same box). This allows units in the field to quickly isolate any batch-lots which become identified as defective. However, munitions lots may be stored at HWAD in different igloos. The use of consolidation sites allows the depot to match-up lots and package them accordingly.

Alternative A is identical to the original baseline simulation where half of the incoming containers are stuffed at the igloo and the remaining are stuffed at a consolidation location. Alternative B requires an investment of capital to reallocate storage locations for munitions. Investment in the hypothetical storage project reduces the reliance on consolidation sites from 50 percent to 30 percent.

Alternative C examines the impact of concrete loading pads slated for completion at HWAD in the Fall of 1995. Currently, CHE operate on unimproved soil-surfaced loading areas (i.e., desert floor). Inclement weather and heavy use can rut the loading areas and hamper container handling. The loading pads provide a stable surface from which to operate the CHEs, and should improve their efficiency by reducing the time

required to pick-up and move a container (MTMC-TEA, 1992 pp. 11). To capture the intention of the loading pad project, the time for each container operation involving CHE was reduced from 20 minutes to 15 minutes. No other changes to parameters were made.

Finally, Alternative D reduces use of consolidation sites, and simulates the impact of container loading pads. In other words, Alternative D combines the two projects to determine if there is any interactive effect between them.

2. Comparison of Alternatives

Before discussing the results of the analysis, the practical applications of project comparisons must first be addressed. The intention of this experiment is to illustrate measures IOC could use as data inputs to a decision support model for prioritizing improvement projects amongst all of its depots. The measure defined by the time to process containers can be used to address questions of operational efficiency **within** HWAD but should not be used to compare HWAD with any other depot. Each depot's unique structural lay-out, and resource mix drive the time required to move, stuff and load a container. If the time to process a container at HWAD is 5.1 hours and the hypothetical time required at Blue Grass is 4.2 hours, one can not assert HWAD is less efficient. The disparity in times may only be attributable to Blue Grass's smaller size, and the shorter travel distance between container loading sites and igloos.

Yet, a comparison can be made between projects at HWAD to determine if an alternative affords a measurable improvement upon current operations as represented by

Alternative A. With some level of statistical confidence, a statement can then be made as to the degree of that improvement.

3. Comparison Analysis

Fifteen replications were conducted for each of the four alternatives. The data output for the simulation runs contains two measures: average container output per day, and average time to process a container. Appendix C provides data tables used for the analysis.

Each of the data runs provides a mean time to process a container. The processing times for the 15 replications were combined to provide an average processing time for each of the four alternatives. A t-Test was then used to determine the mean difference between Alternative A, the base case, and the three proposals. From the t-Test, the degree of improvement was then measured as a percentage derived by dividing Alternative A processing time by that of the project proposals (i.e., Alternatives B through D). Results are contained in Table IV. The analysis supports the assertion that if Alternative B were implemented at HWAD, a two percent improvement would likely be realized. It does not purport that Alternative C, with an expected four percent increase in efficiency, is twice as good as Alternative B, with a two percent expected improvement. The improvement percentage is not intended to be used to rank the projects.

Alternative	Mean Processing Time	Variance	t-Test, α =.05	Improve-ment over Alt. A
A: Base Case	5.12	.0001	N/A	N/A
B: Reduce Consolidation Site	4.92	.0001	26.0	2%
C: Reduce CHE time	4.81	.0004	20.89	4%
D: Reduce CHE time and Consolidation	4.51	.0000	33.79	10%

Table IV. Processing Time Results and Comparison

Analysis of daily container output results for the four alternatives yielded intriguing results. Reducing the reliance on consolidation sites, rather than an improvement, decreased container output. Table V lists the average daily container output for the alternatives.

Alternative	Mean Output	Variance	Standard Error
A: Base Case	119	.106	.084
B: Reduce Consolidation Sites	110	.117	.088
C: Reduce CHE time	154	.117	.088
D: Reduce CHE time and Consolidation	145	.106	.084

Table V. HWAD Container Output

How can operational efficiency be improved at the same time output is decreased? The answer lies within the methods used in AmmoBox to model stuffing containers at igloos and at consolidation sites. If no delays are experienced for equipment, it takes 3.8 hours to process a container at a magazine, and 4.9 hours at a consolidation site. Based

on this difference, one would anticipate a greater number of containers processed through the magazine sites during a day than through the consolidation sites. While 50 percent of the incoming containers go to magazine stuffing locations, more than 50 percent of a day's container output is attributable to these sites.

Stuffing at the magazine calls for a container to be placed on a chassis by a CHE. The container and chassis are then moved to the igloo. In stuffing containers at a consolidation site, a CHE is only required at the end of the process to lift the loaded container onto a rail car or truck. Consequently, as more containers are processed at the magazine, the demand for CHE increase. As previously addressed, CHE are a scarce resource at HWAD. Delays for this equipment may increase the time to process the containers at the magazine, and consequently, decrease the number of containers processed at that site in a day. Even with this small increase in time attributed to waiting for equipment, stuffing at the magazine is inherently more time efficient (3.8 compared to 4.9 hours). Hence the time to process a container using Alternative B can be improved, and simultaneously the output of containers reduced.

Measuring the degree to which a project could improve depot operations has practical application in its use as input data to an optimization model. Container output can also be applied as a constraint in such a model. Chapter V will discuss how these measures could be used in a decision support system for determining funding priority for depot projects.

V. FROM SIMULATION TO OPTIMIZATION

Chapters III and IV detailed the use of simulation to quantify depot operations. Further, container output and processing time were introduced as potential candidates for measuring container operations. This chapter explains how simulations, similar to **AmmoBox**, may be used to generate data which would comprise the basis for a decision support system.

A. DECISION SUPPORT SYSTEM

Linear programming techniques are a tool which could be used to form the basis for a decision support system to assist in funding decisions. "Linear Programming is a mathematical procedure for determining optimal allocation of scarce resources. (Schrage, 1991, pp. 1)." For IOC, the scarce resource is funding dollars, which must be allocated across a list of proposed container enhancement projects. Linear programming models are normally defined by an objective function, and a series of constraints which bound the problem to be solved. In the case of container enhancement projects, budgetary funds serve as a constraint, and the value gained (i.e., enhanced container operations) serves as the objective function. To develop a decision aid based on linear programming, the value of a each project must be defined by some measure (or measures).

It is not the author's intention to mathematically develop a linear program for use by IOC, although the foundation one possible model will be described. The results of

AmmoBox simulations discussed in Chapter IV were employed to develop the objective function and constraints for the following linear programming model.

B. MODEL FORMULATION

This simple model is described below. A more complex, robust model could be further developed using this formulation as its basis.

Indices:

$i = 1, ..., a$	Alternative i at a given depot
$j = 1,..., 11$	Depot j

Simulation Derived and Given Data

Budget	IOC budget
$MinOutput_j$	ASMP minimum required container output for depot j
$ProcessTime_{i,j}$	Percent improvement in processing time for alternative i at depot j
$Output_{i,j}$	Container output for alternative i at depot j
$Cost_{i,j}$	Cost of alternative i at depot j

Decision Variables

$X_{i,j}$	Binary variable representing alternative i at depot j

Objective Function

Maximize $\quad \Sigma_i \; \Sigma_j \; (ProcessTime_{i,j} * X_{i,j}) \qquad$ **(3)**

Constraints

Subject To:	$\Sigma_i \; \Sigma_j \; Cost_{i,j}$	$\leq Budget$	**(4)**
	$\Sigma_i \; (Output_{i,j} * X_{i,j})$	$\geq MinOutput_j \;\; \forall j$	**(5)**
	$\Sigma_i \; X_{i,j}$	$= 1 \;\; \forall j$	**(6)**

The decision variable in this formulation takes on values of either zero or one. If an project alternative were selected for funding, its representative variable $X_{i,j}$ would take

on the value of one. A decision variable $X_{i,j}$ would be created for each IOC project. Additionally, an $X_{i,j}$ variable would also be required for that alternative which represents the current situation (i.e., base case) at each depot, with its associated cost of zero and a process time improvement also of zero.

The objective function (Equation (3)) seeks to maximize improvements to container processing time across all IOC depots. Equation (4) ensures the sum of the costs of the selected alternatives are within the budgetary constraints. Equation (5) allows IOC to establish a minimum daily container output requirement for each depot. Lastly, Equation (6) ensures one and only one alternative is selected for each depot.

C. DISCUSSION

The described integer program shows just one way to optimize funding. The formulation allocates funding dollars across all depots and projects to maximize improvements realized in container processing time. The objective function could as easily direct maximization of container output at each depot. However, as explored in Chapter IV, it is possible to increase output while simultaneously reducing efficiency. By developing minimum output requirements for each depot, IOC would be able to ensure maximum efficiency (i.e., value for dollar) and still meet its ASMP requirements.

VI. CONCLUSIONS

A. SUMMARY OF FINDINGS

The purpose of this thesis was to develop methods and measures IOC could use to prioritize container enhancement projects at its eleven munitions depots. Two methods have been discussed. The first, simulation, allows the decision maker to derive data not currently assessable. Historical data are not readily available, as no IOC depot has performed sustained container operations at mobilization levels. Simulation programs, like **AmmoBox**, can be used to approximate the effect of mobilization on depot operations. The simulation can, in turn, be utilized as a tool to estimate the effect of changes to depot infrastructure and procedures. Through the use of **AmmoBox**, operations at HWAD were examined. Equipment shortages impacting the attainment of mobilization goals were identified.

Two alternative projects, changing consolidation practices (i.e., change to procedures) and the addition of container loading pads (i.e., change to infrastructure), were modeled. From these experiments, data on two measures of container operations, time to process a container and daily container output were gathered.

Simulation can be viewed as the first stage of the process, allowing the analyst to gather data not experientially available. The outputs from a simulation model can be used as the inputs to a decision support model. Chapter V described one such simple decision

model based upon linear optimization. The methods of simulation and optimization could be applied to most of IOC container enhancement projects, however they will not adequately address the viability of *all* ASMP projects. This type of analysis is most applicable to projects which affect container operation output or efficiency. ASMP projects which do neither may be best assessed via alternative forms of analysis. For these anomalies, a form of cost-benefit analysis may prove most practical. Appendix D briefly addresses on such project at Crane Army Ammunition Activity.

B. FURTHER RESEARCH

A myriad of factors impact depot capability to ship munitions in containers. **AmmoBox** concentrated on two key components, equipment resources and container handling procedures. Facets such as Net Explosive Weight (NEW), and depot rail and road infrastructure are important, and need to be incorporated into future depot simulation models (Straight, 1995).

This thesis, as well as MTMC-TEA assessments, have made assumptions which may be unrealistic. Most notably, studies have assumed an unconstrained availability of empty containers. A depot's capability to output containers of ammunition is predicated on the depot receiving a steady flow of empty containers to load. Given current planning factors for shipping munitions, the Army simply does not own a sufficient number of containers to supply the depots during a major mobilization. The availability of containers is a recognized issue, and has recently been the focus of a MTMC-TEA study (Shuck,

1994). Prepositioning containers at depots is yet another area requiring further investigation.

Lastly, this research focused exclusively on munitions depots, and ignored the other elements of the munitions logistics system. When viewed in its entirety, the system acts like a network. The depots serves as a source node and the end user in the field, the demand node. Between the depot and the field are flow points, for example seaports and rail terminals.

> Starting at the sources of ammunition supply and moving toward the users, each point along the way has less capability to handle the workload than the one before it. So, if the depots and plants begin to outload at full capacity, they will overload the ports. If the ports load ships at full capacity, the in-theater receiving capability will be quickly overwhelmed and unable to move ammunition to the users...Increases in capacity at the CONUS end must be accompanied by similar increases at other nodes in the system to achieve balance (Volpe National Transportation Center, 1993, pp. I-6).

Further research is needed to link the impact of depot enhancement projects to other nodes within this logistics network. A seaport-throughput, simulation-based, model was recently developed by Argonne Laboratories for MTMC-TEA. Extending this new model to encompass the munitions depots may be a valuable step towards linking the depots to the munitions logistics network.

APPENDIX A. HAWTHORNE ARMY DEPOT RESOURCES AND CONTAINER OPERATION PARAMETERS

Type	Quantity	Reliability	Availability
Forklifts	106	80%	80%
Transfer Tractors	26	80%	85%
Transfer Semi-trailers	24	80%	85%
Container Handling Equipment (CHE)	7	50% [1]	100%
Chassis	81	75%	100%

Table VI. Equipment Resources

Hours of operation per day	20 hrs
Percentage of containers moved by truck	28%
Percentage of containers moved by train	72%
Number of container inspection sites	5 [2]
Amount of time to load container from chassis to rail car	20 mins.

Table VII. Depot Operations

Maximum number of trucks cycled through the depot (per day)	50
Number of rail cars per train	37
Number of containers on a rail car	3.5

Table VIII. Transportation Information

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1. Hawthorne reported 50 percent reliability. Author modified CHE reliability to be more consistent with that reported by MTMC-TEA.

2. Figure based on author's judgment of inspection sites required to maintain a steady supply of containers to operations.

Number of magazine work sites	10
Number of containers to be stuffed at each magazine	8
Number of containers worked simultaneous at each work site	2
Average time to stuff a container (includes set up time for stuffing site)	2.1 hrs
Average transit time to stuffing site	.5 hr
Number pre-staged containers	48
Full mobilization container output goal per day	188
Percentage of arriving containers which require repair	20% [3]
Average time to repair damaged containers	4 hrs [4]

Table IX. Container Operations

Step	Time (in hours)	Equipment Requirements
Load container on chassis	.33	Chassis and CHE
Transit to magazine	.5	Chassis and tractor
Stuff munitions into container	2.1	Chassis and two forklifts
Transit from magazine	.5	Chassis and tractor
Load container on rail car or truck	.33	CHE

Table X. Container Loading At Munitions Magazines

Step	Time (in hours)	Equipment Requirements
Semi-trailer transits to magazine	.5	Semi-trailer and tractor
Load munitions into semi-trailer	.5	Semi-trailer and two forklifts
Transit to consolidation site	.5	Semi-trailer and tractor
Discharge munitions from semi-trailer	1	Semi-trailer and two forklifts
Stuff munitions into container	2.1	Two forklifts
Load container on rail car or truck	.33	CHE

Table XI. Container Loading At Consolidation Sites

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3. Hawthorne reported a 65 percent container rejection rate. Results from TURBO CADS 94 indicated a much lower container rejection rate.

4: Repair times vary widely. **AmmoBox** employs a triangular distribution where repair times range from one to nine hours.

APPENDIX B. HWAD MOBILIZATION DATA

FACTOR-LEVEL			REPLICATION					
Inspection Sites	Transfer Tractors	CHE	1	2	3	4	5	Mean
H	H	H	211	211	211	212	212	211
M	H	H	211	210	211	212	211	211
L	H	H	189	189	190	190	190	190
H	M	H	207	207	207	206	207	207
M	M	H	207	207	207	206	207	207
L	M	H	190	189	190	190	190	190
H	L	H	200	201	201	201	200	201
M	L	H	202	203	201	200	200	201
L	L	H	189	190	191	190	190	190
H	H	M	190	190	190	190	191	190
M	H	M	186	187	187	187	187	187
L	H	M	174	174	174	175	175	174
H	M	M	190	190	190	190	190	190
M	M	M	186	187	186	186	187	186
L	M	M	175	175	175	175	174	175
H	L	M	190	190	190	190	191	190
M	L	M	186	187	187	187	187	187
L	L	M	174	176	175	175	175	175
H	H	L	166	167	167	167	168	167
M	H	L	165	165	166	166	167	166
L	H	L	159	160	160	160	160	160
H	M	L	167	167	166	167	167	167
M	M	L	165	166	165	166	166	166
L	M	L	159	160	160	160	159	160
H	L	L	166	167	167	168	168	167
M	L	L	165	166	165	167	166	166
L	L	L	159	159	160	160	161	160

Legend

Inspection Sites:	H = 7	M = 6	L = 5
Transfer Tractors:	H = 32	M = 30	L = 28
CHE:	H = 13	M = 11	L = 9

APPENDIX C. HAWTHORNE ARMY DEPOT (HWAD) COMPARISON OF PROJECTS

This appendix provides data from simulations using the model, **AmmoBox**. Four alternatives were reviewed and their impact on container output and processing time assessed. The alternatives are as listed:

- Alternative A: Current depot operations;
- Alternative B: Increase the percentage of incoming containers processed at the magazines from 50 to 70 percent;
- Alternative C: Decrease CHE handling time from 20 to 15 minutes;
- Alternative D: Decrease CHE handling time, and increase magazine loading of containers.

Replication	Alternative A	Alternative B	Alternative C	Alternative D
1	5.13	4.93	4.8	4.52
2	5.15	4.92	4.8	4.52
3	5.14	4.93	4.86	4.5
4	5.12	4.92	4.81	4.51
5	5.12	4.93	4.81	4.52
6	5.11	4.92	4.8	4.52
7	5.14	4.9	4.8	4.51
8	5.12	4.9	4.8	4.52
9	5.13	4.92	4.78	4.52
10	5.13	4.9	4.81	4.51
11	5.11	4.93	4.8	4.52
12	5.13	4.93	4.84	4.52
13	5.13	4.92	4.8	4.51
14	5.12	4.93	4.8	4.51
15	5.12	4.92	4.81	4.51

Table XII. Time To Process Containers (in hours)

Alternative	Mean	Standard Error	Variance
Alternative A	5.12	.0029	.0001
Alternative B	4.92	.0029	.0001
Alternative C	4.81	.0049	.0004
Alternative D	4.51	.0017	0000

Table XIII. Descriptive Statistics for Time to Process

Comparison	Pooled Variance	Mean Difference	Degrees of Freedom	t-Test Statistic
Alternative A and B	.00013	0.1	28	26.004
Alternative A and C	.00012	.2	28	20.895
Alternative A and D	.00012	.5	28	33.794

Table XIV. Comparison of Alternative A with Alternatives B-D (Time to Process)

Replication	Alternative A	Alternative B	Alternative C	Alternative D
1	118.6	110.5	153.7	144.2
2	118.2	110	153.5	145
3	118.7	110	153.6	144.3
4	119.1	109.8	154	144.3
5	118.6	110.4	153.4	144.7
6	118.9	110.5	153.5	145
7	118.4	110	153.4	144.2
8	119.1	110	152.9	144.5
9	119.1	110.6	153.5	144
10	119	109.7	153.7	144.4
11	118.5	110.9	153.7	145
12	118.5	110.3	153.9	144.2
13	118.9	110.2	153	144.5
14	119.4	110.6	154.2	144.5
15	118.7	110	153.8	144.8

Table XV. Container Output per Day

Alternative	Mean	Standard Error	Variance
Alternative A	118.9	.0841	.106
Alternative B	110.2	.0881	.1167
Alternative C	153.6	.0883	.1170
Alternative D	144.5	.0842	.1064

Table XVI. Descriptive Statistics for Container Output

APPENDIX D. CRANE ARMY AMMUNITION ACTIVITY

Container output and processing time measures may not adequately address all of the IOC projects. A proposal to build a container repair facility at Crane Army Ammunition Activity (CAAA) is one such project. CAAA is a Tier-One depot located as a tenant command at Naval Surface Warfare Center-Crane, Indiana. CAAA's mission is to produce and renovate; store and ship; and demilitarize and dispose of conventional ammunition. A 1993 Army Strategic Mobility Plan Study recommended several corrective actions to enable CAAA to meet its mobilization requirements, and included a proposal to build a MILVAN Repair/Inspection Facility (URS, 1993, pp. 2). Current practice requires defective containers be returned to their source, primarily, Sunnypoint, North Carolina.

A. BACKGROUND

The proposed container repair facility would be collocated with a new containerization facility, and containers would be inspected at a single site instead of the four locations currently in use. If a container was found to be defective, it could be repaired at its inspection location. CAAA estimates it will be able to repair 95 percent of damaged containers with the new facility. The remaining five percent would be returned to their source for disposal or repair.

The repair facility is unlikely to increase CAAA container output capability. To judge the viability of the project wholly on container output or processing time would be

a mistake. This project has the potential to save the government transportation costs associated with returning unusable containers. This cost is substantial. The cost of shipping a empty container to Sunnypoint is $2612. The cost of building the repair facility is $1.45 million (CAAA, 1994). The remainder of this chapter will compare these expenses over a ten-year period using two scenarios. The results from the assessment are not intended for incorporation into an optimization-type model. They are, instead, an example of factors which may require independent consideration from any IOC-adopted decision support model.

B. METHODOLOGY

A simple economic analysis was conducted contrasting two alternatives, over two scenarios. Alternative A portrays CAAA's current situation, and Alternative B represents CAAA with a new container repair facility. The first scenario examines the costs incurred during peacetime for the two alternatives. The second scenario explores the impact of a major contingency (e.g., mobilization) occurring at year six in a ten-year period. Assumptions used for both scenarios are summarized as follows.

- The container repair facility is built in year 1 of the scenario.
- The cost of the container repair facility is $1.45 million.
- On average, 150 containers are processed each year.
- The rejection rate for containers is 20 percent.
- In Alternative B, 5 percent of the rejected containers could not be repaired.

- A labor rate of $40.68 was used. In Alternative A, extra labor costs were charged against rejected containers at a rate of $13.56 each.
- Labor and material costs to repair the container were the same for Sunnypoint and CAAA.
- Rejected containers are returned to Sunnypoint, for a transportation cost of $2612 each.
- A discount rate of 8 percent was used. Net present value of alternatives were compared at the end of year 10.

C. PEACETIME SCENARIO

Currently, CAAA handles approximately 150 containers a year (CAAA, 1994). Given a rejection rate of 20 percent, 30 of these containers require repair. These figures were used to compute a ten year cost cycle to determine the Net Present Value (NPV) of building a repair facility as opposed to returning defective containers to their source. In this analysis, the labor and material costs associated with repair of the container was assumed to be the same regardless of the location. A transportation cost of $2612 was assessed against each rejected container. This cost is conservative as it takes into account only returning the rejected container, and does not capture the cost of shipping a replacement container to CAAA.

Results found that during normal operations, it is more cost effective to return the containers to their source. The NPV for Alternative A, no repair facility, was $528,532. In contrast, the NPV for CAAA with a repair facility was $1,403,552. The wide disparity in values suggest small variances in assumptions will make no difference in the ranking of the two alternatives. A sensitivity analysis showed CAAA would need to process 450

containers a year before it became more advantageous to build a container repair facility. A list of thresholds for parameters is provided in Table VI.

Parameter	Range of Parameter	Parameter Threshold
Number of containers per year	150-450	450
Rejection rate of containers	20-60%	60%
Discount rate	8-20%	Did not change ranking
Life cycle length	10 -20 years	20 years

Table XVII. Peacetime Scenario Sensitivity Analysis

D. MOBILIZATION SCENARIO

In Scenario 2, a major mobilization occurs at year six. The other years are handled with the same assumption as in the peacetime scenario. During the contingency, operations at CAAA reach the required ASMP levels of 104 containers a day (CAAA, 1994). This tempo of operations is sustained for 30 days for a total of 3120 containers processed during the surge. The same number of containers are retrograded (i.e., returned) to the facility. The total number of containers handled by CAAA during year six is then 6240.

Further, transportation costs for rejected containers, during surge operations, are doubled. The two-way transportation charge is justified for two reasons. First, insufficient MILVANs exist within the Army system to accommodate a major crisis. Containers thus become a valuable commodity and a container needlessly in transit is a wasted resource. Second, if a container is rejected, a replacement is required. The Army

then has paid for the round-trip transportation of an unused commodity and the $5624 charge is a more realistic assessment of actual costs.

Results show, given a major contingency, the CAAA container repair facility will accrue substantial savings for the Army (See Figure 5).

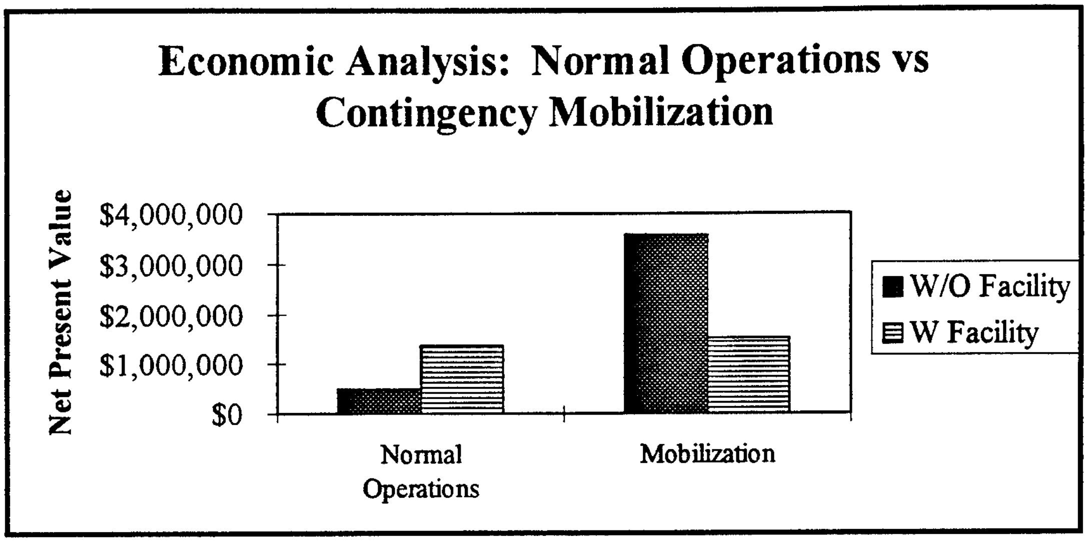

Figure 5. Net Present Value of CAAA Container Repair Facility Alternatives

The dramatic increase in container use during mobilization causes a corresponding increase in transportation costs. The timing of the crisis, within the ten-year life cycle impacts the costs but not the overall result. Regardless of whether a contingency occurs at year three or year ten, it is always less expensive to have built the repair site. Figure 4 graphically portrays the two scenarios and their associated costs in terms of NPV.

The economic value of building a container repair facility at CAAA yields conflicting results. If one assumes normal operations for the activity, then it is not cost effective to build the repair facility. Conversely, given a mobilization scenario such as Desert Storm, the opposite is true. Which scenario used, peacetime or mobilization, is a

decision for policy makers. The importance of this analysis is to illustrate that a project may be cost-effective and viable, even if no improvement on depot efficiency or output is anticipated.

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